Sea Ice Thickness from Satellite, Aircraft, and Model Data

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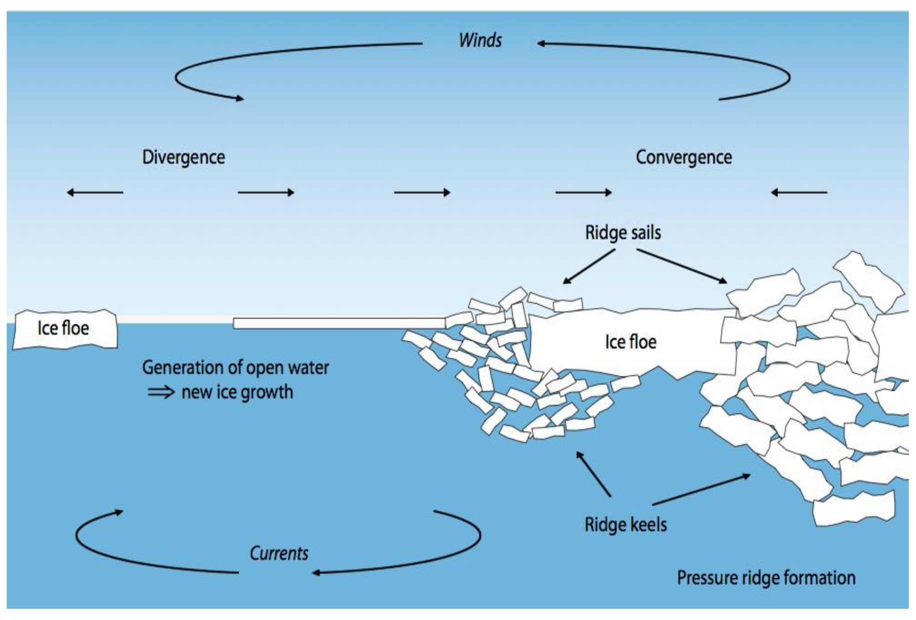
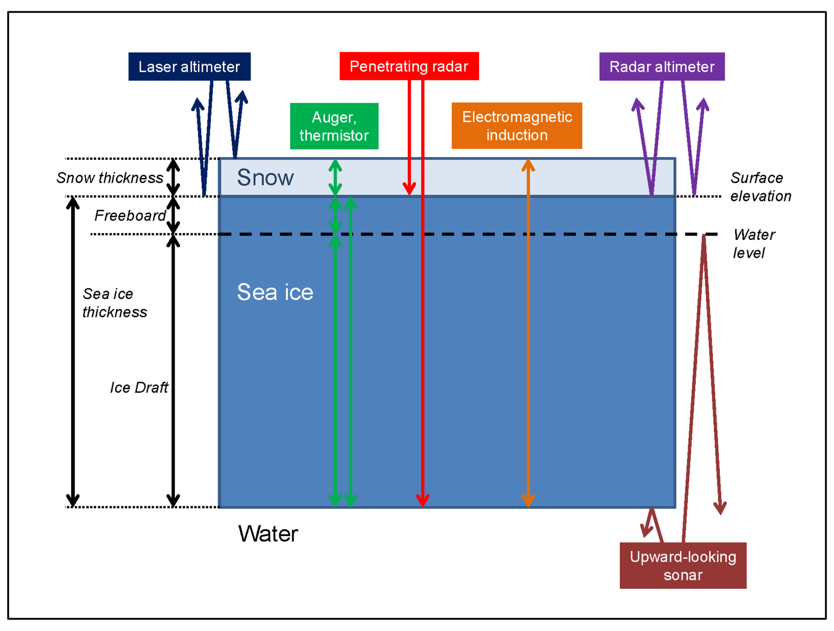
Introduction

Sea ice extent and thickness affect the exchange of heat, energy, mass, and momentum between the atmosphere and the underlying ocean, and therefore play a significant role in weather and climate of the polar regions. Sea ice also has profound socio-economic value due to its critical impact on transportation, hazards, recreation, fisheries, and hunting. Conventional observations of sea ice properties are sparse, particularly sea ice thickness. Thus, satellite remote sensing data play a key role in estimating and monitoring changes in sea ice. With recent advances in remote sensing technology, it is now possible to estimate ice thickness from space using a variety of techniques, each having advantages and disadvantages. The One-dimensional Thermodynamic Ice Model (OTIM) is an energy budget approach for estimating sea and lake ice thickness with optical (visible, near-infrared, and infrared) satellite data from sensors such as the Advanced Very High Resolution Radiometer (AVHRR), the Moderate Resolution Imaging Spectroradiometer (MODIS), and the Visible Infrared Imaging Radiometer Suite (VIIRS). A very different approach uses lidar or radar altimeter data from the ICESat and CryoSat-2 satellites to measure ice elevation (freeboard), from which ice thickness can be estimated. Yet another method employs low-frequency microwave data from the Soil Moisture and Ocean Salinity (SMOS) mission. The energy budget approach works best for thin to moderately thick ice, altimeters have limited coverage, and the passive microwave approach is for thin ice only. All approaches are influenced by uncertainties in the depth of snow on the ice, surface melt, and other factors.

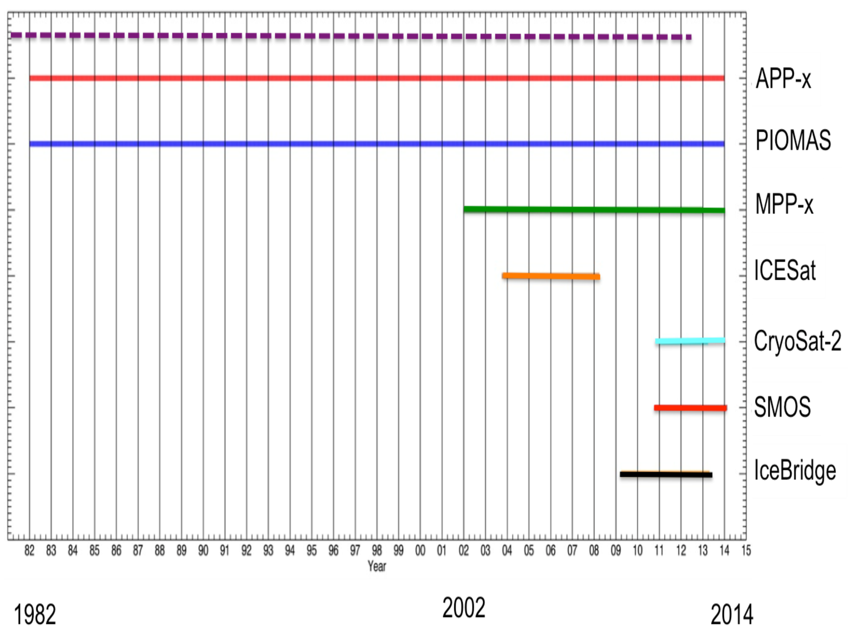
In this study we compared sea ice thicknesses from seven datasets: the Extended AVHRR Polar Pathfinder (APP-x), a similar product from MODIS, ICESat from the Jet Propulsion Lab, CryoSat-2 from the Alfred Wegener Institute, SMOS from the University of Hamburg, and NASA IceBridge aircraft flights. Additionally, the satellite products are compared to ice thickness from the Pan-Arctic Ice Ocean Modeling and Assimilation System (PIOMAS). The intercomparison is complicated by the fact that the datasets cover different time periods and spatial resolutions, with the APP-x and PIOMAS having the longest record (1982 – present). Comparisons are done for the period of overlap between all datasets, with PIOMAS as a reference data set. Preliminary results show that sea ice thickness from APPx, MODIS, PIOMAS, CryoSat-2, and NASA IceBridge agree reasonably well overall, though there are important differences that arise from limitations of the different sensors and methods. SMOS appears to underestimate the overall sea ice thickness, and ICESat likely overestimates sea ice thickness in coastal areas along Canadian archipelago.



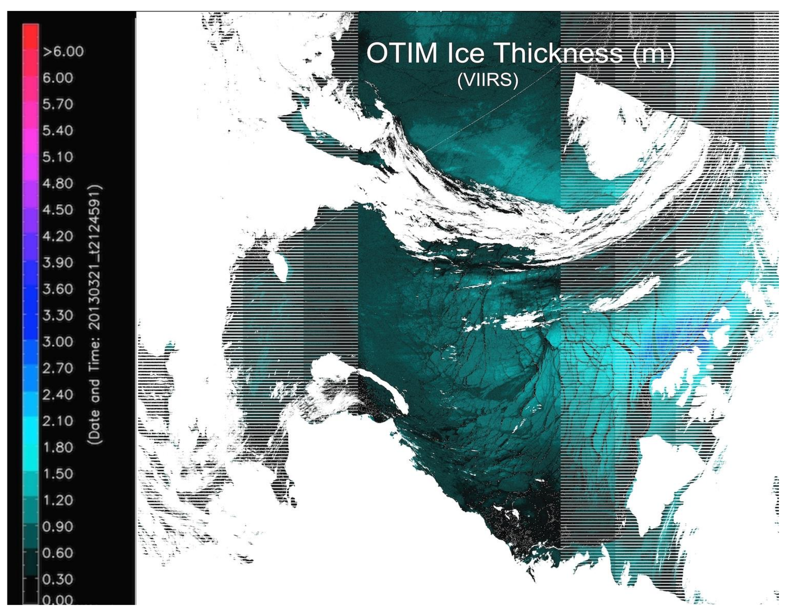
Processes that affect ice thickness. *(from SWIPA, 2011)*



Measuring ice thickness with different approaches. (Adapted from *Meier et al., 2014)*

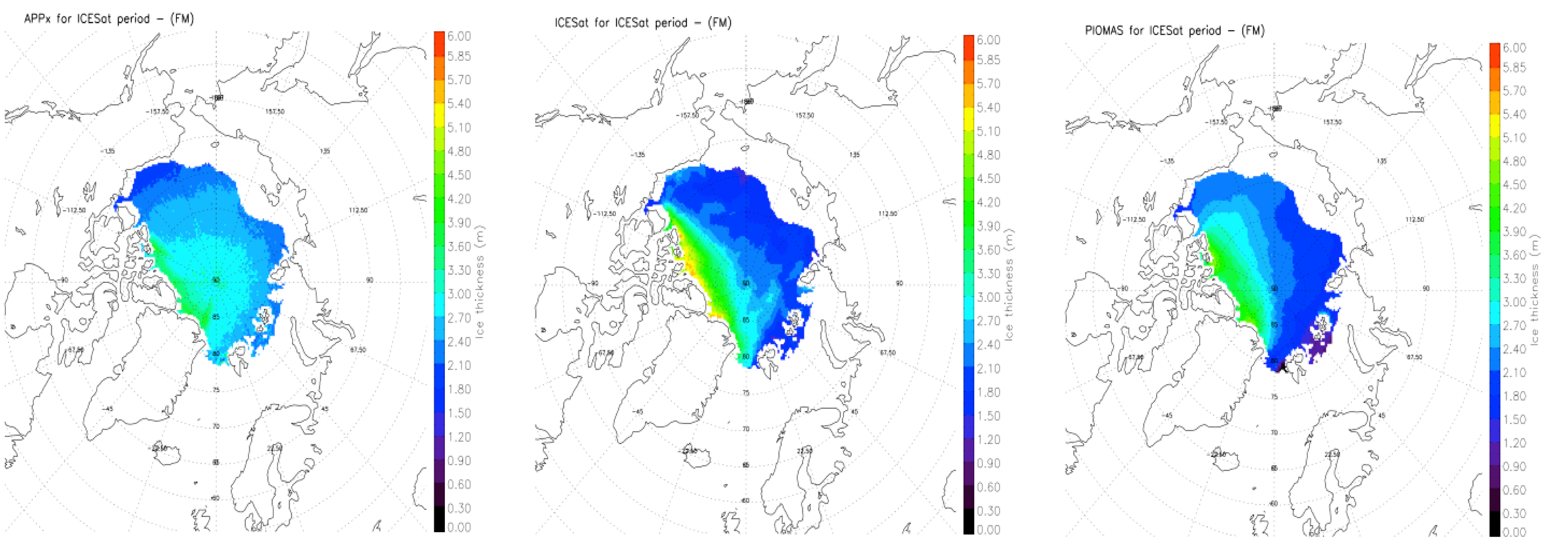


Research datasets and their corresponding time periods.

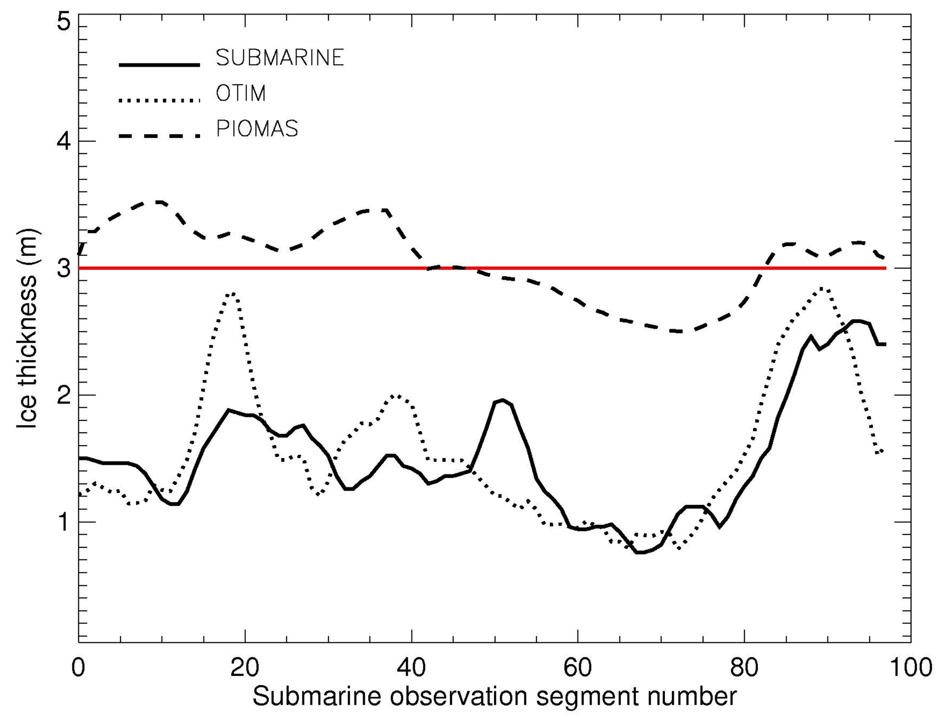


Based on S-NPP VIIRS data with the One-dimensional Thermodynamic Ice Model (OTIM) for March 21, 2013.

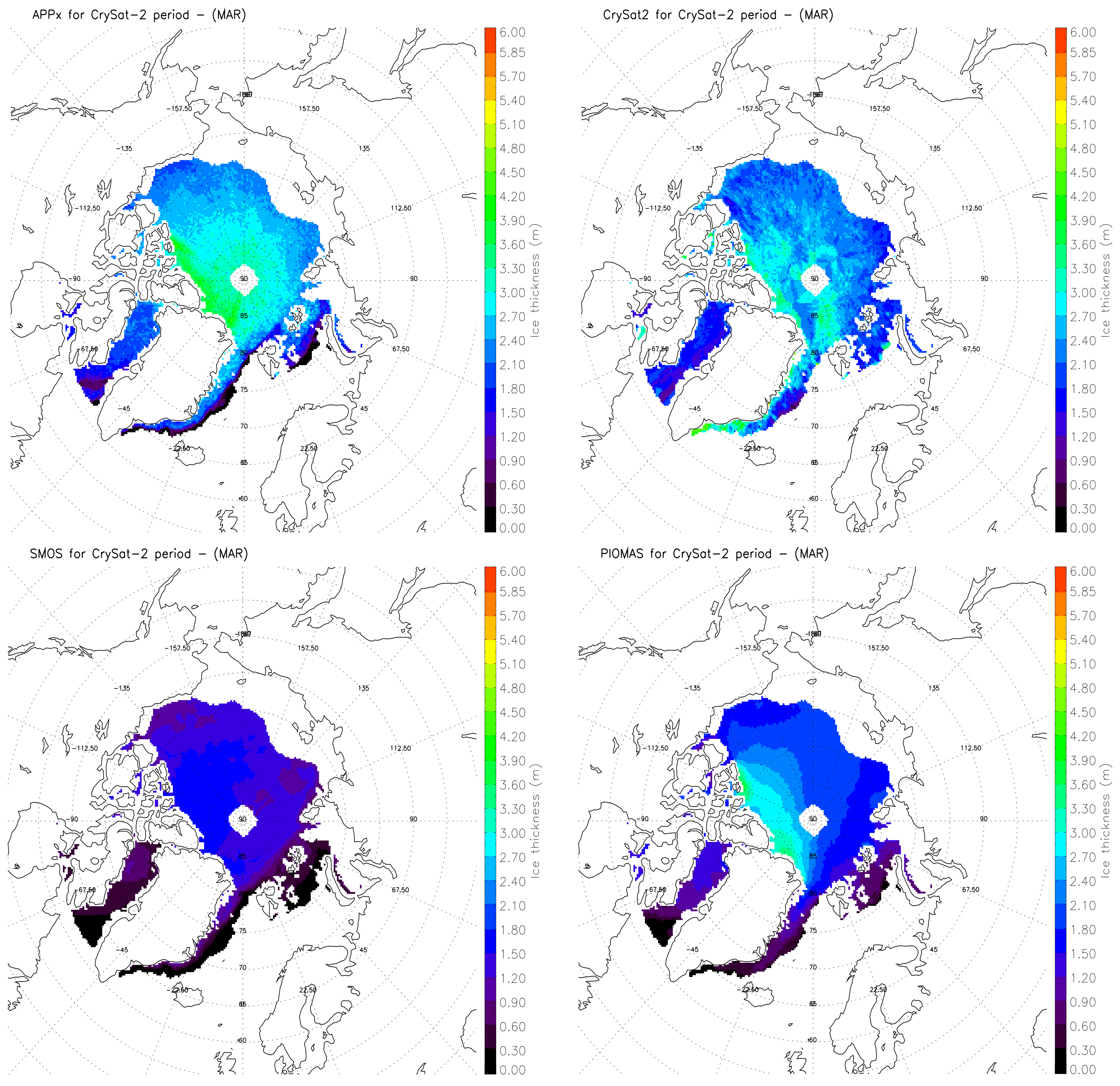
APP-x ICESat PIOMAS



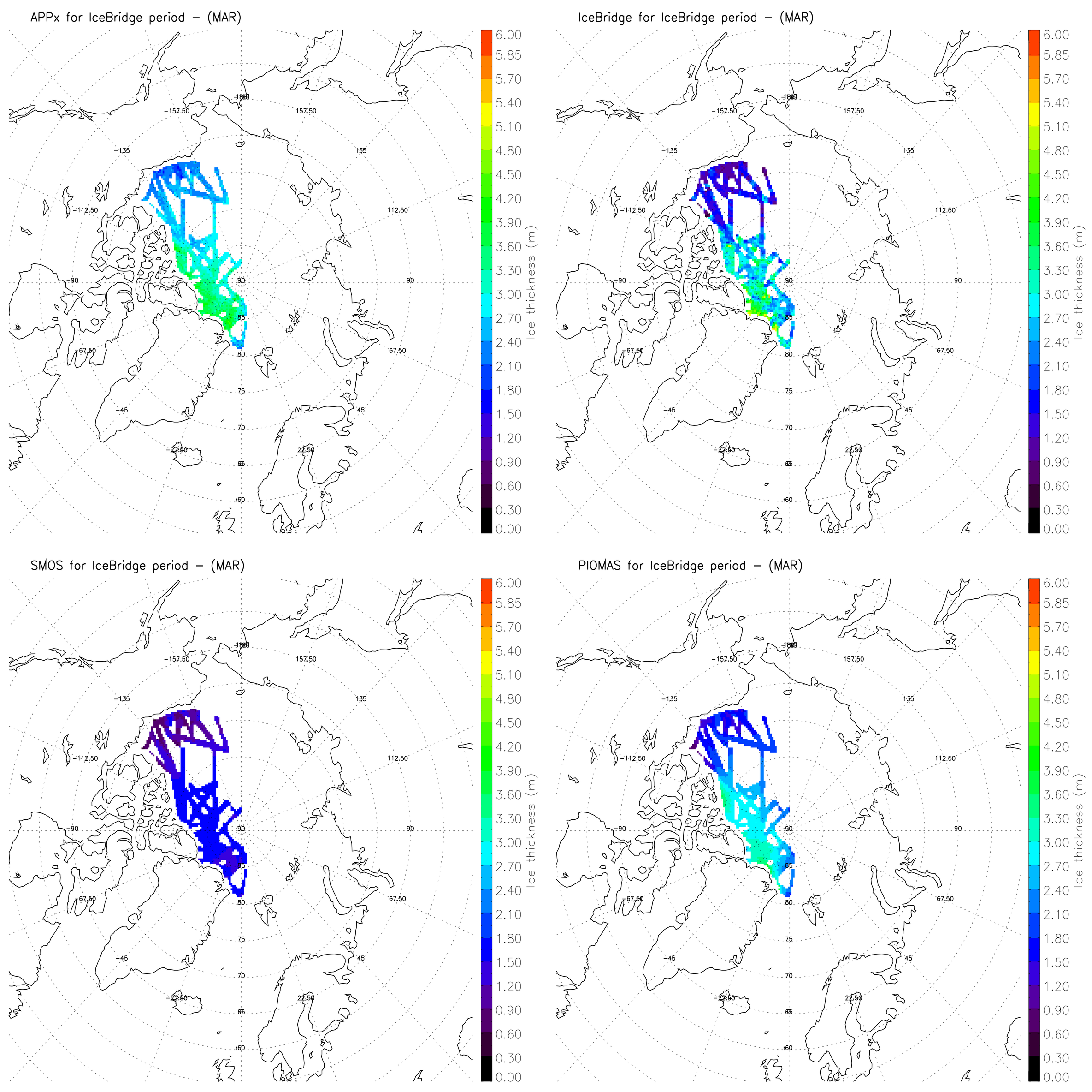
Arctic sea ice thickness from APP-x (left), ICESat (middle), and PIOMAS (right) for the period of October 2003 to March 2008 on February-March average only. The mean bias between APP-x and PIOMAS is 0.02 m, and the mean bias between ICESat and PIOMAS is 0.35 m.



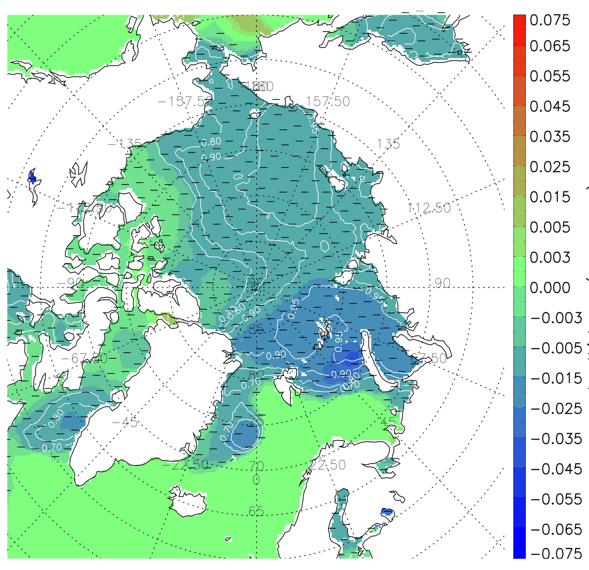
Comparisons of ice thickness retrieved by OTIM with APP-x data, measured by submarine, and simulated by PIOMAS alone the submarine track segments. Overall bias between OTIM and submarine is 0.04 m, and its RMS is 0.52 m.



Inter-comparisons of Arctic sea ice thickness from APP-x, CryoSat-2, SMOS, and PIOMAS for the CryoSat-2 period from January 2011 to March 2013 in terms of monthly mean (March).



Inter-comparisons of Arctic sea ice thickness from IceBridge, APP-x, CryoSat-2, SMOS, and PIOMAS for the IceBridge period from March 2009 to April 2013 in terms of monthly mean (March).



Arctic sea ice thickness trend in meter per year over 1982-2013 from APP-x dataset.

Conclusion

•The inter-comparison is complicated by the fact that the datasets cover different time periods and spatial resolutions, with the APP-x and PIOMAS having the longest record (1982 – present). Comparisons are done for the period of overlap between all datasets, with PIOMAS as a reference data set. Results show that Biases relative to PIOMAS range from -0.3 (SMOS) to +0.5 (CryoSat-2, ICESat, APP-x, MPP-x). SMOS is intended for thin ice estimates only. All products show thinning Arctic sea ice since 1980.

•Trends range from less than 1 cm/year to 6 cm/year for some areas in the Arctic ocean. Multiyear ice is far less prevalent now than 20 years ago. Young, thinner ice melts more easily, deforms much more easily, moves faster, and is therefore exported more readily.

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